ANALYSIS

41(188), October 1, 2015

ISSN 2278–5469
EISSN 2278–5450

Discovery

Integrated water resources management with special reference to water security in Rajasthan, India

Kuldeep Tiwari[1], Rohit Goyal[2], Archana Sarkar[3], Priyamitra Munoth[4]

1.PhD Scholar, Malaviya National Institute of Technology Jaipur, Jaipur, Rajasthan 302017, India; Email: Email: 2012rce9506@mnit.ac.in
2.Professor, Malaviya National Institute of Technology Jaipur, Jaipur, Rajasthan 302017, India; Email: rgoyal.ce@mnit.ac.in
3.Scientist 'D' National Institute of Hydrology, Roorkee, Uttarakhand, – 247667, India; Email: archana_sarkar@yahoo.com
4.PhD Scholar, Malaviya National Institute of Technology Jaipur, Jaipur, Rajasthan 302017, India; Email: 2014rce9536@mnit.ac.in

Publication History
Received: 10 July 2015
Accepted: 29 August 2015
Published: 1 October 2015

Citation
Kuldeep Tiwari, Rohit Goyal, Archana Sarkar, Priyamitra Munoth. Integrated water resources management with special reference to water security in Rajasthan, India. *Discovery*, 2015, 41(188), 93-101

ABSTRACT

Fresh water is valuable natural resource for living organisms, which is being continuously depleted. Water Security means regular access and equity to safe potable water for drinking, sanitation and hygiene thereby leading to an acceptable physical and social well being. Integrated water resources management (IWRM) practices are needed to create sustainable water security. IWRM is a conceptual stakeholder participatory framework that could manage and develop the water resources in a sustainable and balanced way. It is based on the principles of social equity, economic efficiency and environmental sustainability. IWRM has been globally accepted as the water management doctrine for the 21st century. This paper presents a critical review of IWRM approach and highlights the challenges related to Rajasthan. This state is considered to be most crucial due to the insufficient water resources. State receives an average annual rainfall of 575 mm. The surface water availability in the state is 16.05 billion cubic meter (BCM). Total annual replenishable ground water of the state is 11.94 BCM out of which the natural discharge is 1.11 BCM during non-

monsoon period and net annual ground water availability is 10.83BCM. Agriculture dependency on ground water is 70-90 %. The per capita water availability for the state is 640 cubic meters which is very low according to international standard of 1000 cubic meter. Water security would lead to efficient water supply system, use of water saving techniques and improved irrigation practices. Special attention is required for rainwater harvesting and conservation techniques and re-use of waste water. Conclusions are drawn and recommendations made based on the current status of water resources of Rajasthan.

Keywords: water resources management (IWRM), Water Security, Fresh water, Rainwater harvesting

1. INTRODUCTION

Integrated water resources management (IWRM) has been globally accepted as the water management doctrine for the 21st century. IWRM is "a process which promotes the coordinated development and management of water, land and related resources in order to maximize social welfare and economic development in an equitable manner without compromising the sustainability of vital ecosystems and the environment" (GWP, 2000). Sustainability of water resource supports to complete social objectives into future without decreasing hydrological and environmental integrity (Davis, 2004). There are certain IWRM studies in other regions of the world (Ferreyra, and Beard, 2007; Grigg, 2008; Ako et al., 2010), however they are usually concentrated on public participation. IWRM approach for the semi-arid regions is considered to be very important due to the inadequate availability of water resources (Singh et al., 2002). Davis (2004) has conducted a study of Chile and found that water quality degradation, increased water user conflicts, recognition of economic inefficiencies and public good issues makes it necessary that a more integrated and watershed based approach to water resource management is adopted.

The agricultural sector is an important consumer to water. Primary agriculture plays a vital role in the food security. Morison et al. (2007) examined that agriculture accounts for 80–90% of all freshwater used by humans, and most of that is in agriculture production at global level. Gao et al. (2014) revealed that agriculture has a greater preference for water saving than other sectors. Improving the water transportation method could lead to 62.1% of the total water savings for the agriculture sector.

Gao et al. (2014) applied multi-objective optimization method to investigate the reduction of freshwater consumption and the total water supply cost. By applying water conservation techniques in Tianjin, China they showed that the local freshwater use could be reduced by 21.5% and the average water costs also decreased by 12.7%. Grigg (2008) defined seven key elements for integration in IWRM such as policy sectors, water sectors, government units, organizational levels and functions of management, geographic units, phases of management and disciplines & professions. Ako (2010) examined the institutional framework for IWRM in Cameroon and concluded that reforms such as public participation at local levels, esteem of water as both a social and an economic entity, putting the exploitation of mathematical models within hydrological basins will improve IWRM in Cameroon.

Effective management of water resources for water scarcity is a critical policy issue in the arid regions (Hu et al., 2014). IWRM looks attractive concept for water security but a deeper analysis brings out many problems, both in concept and implementation, especially for meso to macro-scale projects (Biswasa, 2004). Giordano and Shah (2014) discussed on pragmatic solutions to existing water problems as they explained issues and examples of trans boundary water governance. In general, groundwater management in India and rural– urban water transfer in China to show that there are alternatives of IWRM to solve successfully major water problems. The world is moving towards a very dangerous situation of societal instability due to our failing ability to manage the water resource system. Water-dependent and water-impacting activities have to be analyzed jointly and attention will have to be paid to water security, food security and environmental Security (Falkenmark, 2001). Water and its security are examined by Stucki et al. (2012) in relation to energy, food security, vulnerability, virtual water flows, and water-related agreements.

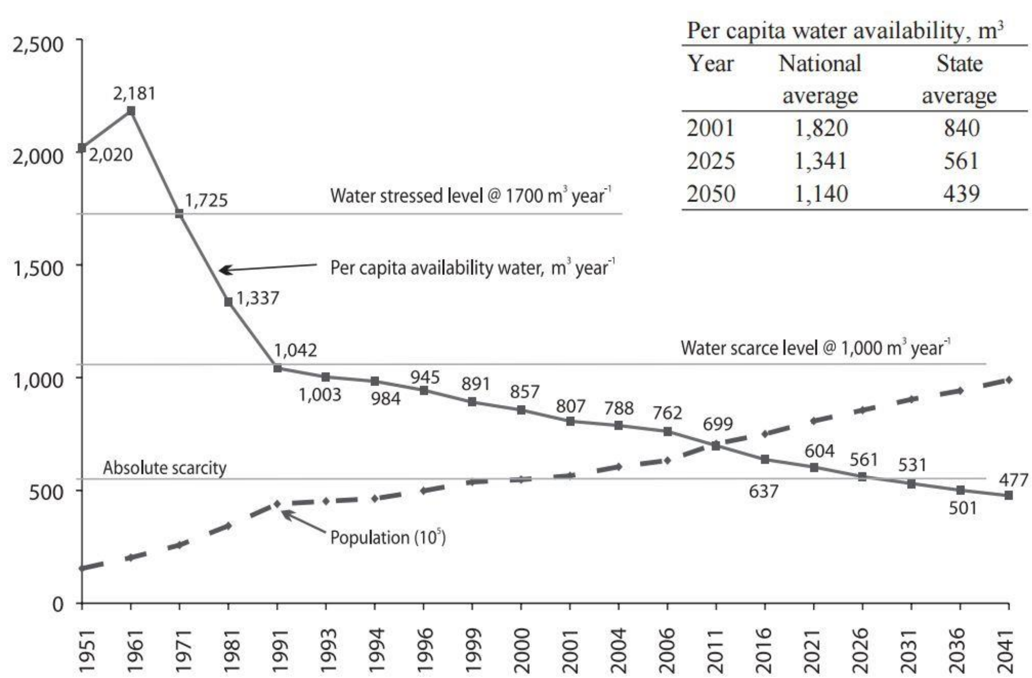
2. NATIONAL WATER RESOURCES SCENARIO

India occupies 17% of the world's population but only 2.45% of the world's geographical area and 4% of the world's water resources. India also has an about 20% of the world's total livestock population which is 500 million. The rainfall is the primary source of fresh water or ground water recharge which is highly uneven over space and time during monsoon season. The total utilizable water resources of the country are assessed as 1086 km^3. A brief description of surface and groundwater water resources of India is given table 1. India's demand for water is outstripping its supply. The total water available in live storage of 91 reservoirs in the country being monitored by Central water commission (CWC) was 91.073 Billion Cubic Meters (BCM) as on Aug.2015. This is 58% of the total live storage capacity of these reservoirs and 92 % of average availability during last 10 years (CWC, 2015). The annual potential natural groundwater recharge from rainfall in India is about 342.43 km^3, which is 8.56% of total annual rainfall of the country.

Table 1 India's Water Resources

S. No.	Water Resource India at a Glance	Quantity (km^3)	Percentage
1	Annual precipitation (Including snowfall)	4000	100.0
2	Precipitation during monsoon	3000	75.0
3	Evaporation + Soil water	2131	53.3
4	Average annual potential flow in rivers	1869	46.7
5	Estimated utilizable water resources	1123	28.1
6	Surface water	690	17.3
7	Replenish able groundwater	433	10.8
8	Storage created of utilizable water	253	22.5
9	Storage (under construction) of utilizable water	51	4.5
10	Estimated water need in 2050	1450	129.0
11	Estimated deficit	327	29.0

Source (http://www.india-wris.nrsc.gov.in/)



(Source: Narain et al.; 2005)

Figure 1 Per capita water availability

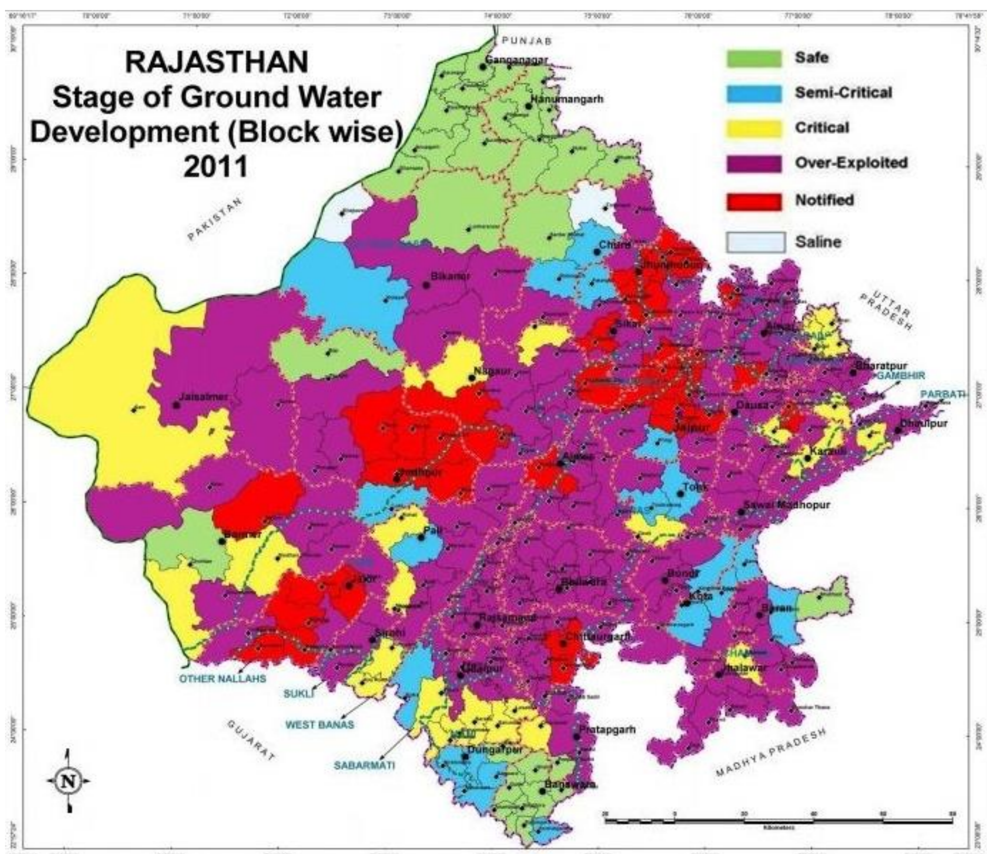
3. RAJASTHAN STATE WATER RESOURCE SCENARIO

Rajasthan is the largest state of India covering an area of 34.2 million ha with 66 % desert, amounting to 10.4 % of the total geographical area of the country, 68 million inhabitants that forms 6.57 % of India's total population (census 2011). As per the 19th livestock census 2012, there are 57.73 million livestock. The primary source of livelihood comprises livestock and agriculture which

places huge demand on the water resources in the driest state of the country. More than 70 % of live stoke population is dependent on agriculture and its related different activities. To support agriculture, livestock and all other water-dependent activities, the state water resources comprise just 1 % share of India.

State receives average annual rainfall of 575 mm. There is wide variations in the average rainfall throughout the Rajasthan with the average rainfall ranging from less than 100 mm to over 400 mm in the western Rajasthan whereas in eastern Rajasthan the rainfall ranges from 220 mm to 1020 mm. (Teri, 2011). The yearly total rainfall is highly variable all over the state. It is most erratic in the western half, with frequent spells of drought as shown in table 2, punctuated occasionally with heavy downpours in some years. The average relative humidity in Rajasthan varies from 60%-65%.

The per capita water availability for the state is 640 cubic meters which is very low according to international standard of 1000 cubic meter as shown in figure. 1. It is also continuous decreasing. Due to rapid growth of population, the scarcity of water will increase leading to further decrease in per capita water availability in the state. Continuous depletion of ground water is bringing Rajasthan in absolute scarcity category as shown in figure 2. Block wise analysis of development status of ground water when categorized into safe to over exploited stages indicate that 13.33% fall into safe category, 9.05% into semi-critical, 14.46% into critical, 50.40% into over-exploited, 11.66% into over exploited (notified) and remaining 1.10% into saline category. Overuse of ground water resources is critically affecting the availability of drinking water security in such blocks. Part of the state water security aspects such as ground water conservation and recharge practices needs special considerations and should be dealt in consultation with all stakeholders. Total Annual Replenishable groundwater resource of the state has been estimated as 11.94 (BCM). Keeping provision for natural discharge of 1.11 BCM during non-monsoon period, net annual groundwater availability in the state has been assessed as 10.83 BCM. Total annual groundwater withdrawal for all uses has been assessed to be 14.84 BCM with the major usage being that for irrigation at 13.13 BCM (88.48%) of total groundwater withdrawal. Overall stage of groundwater development of the state has been estimated as 137% (CGWB 2015).



(Source: hydrogeological atlas of Rajasthan 2013)

Figure 2 Ground water development map of Rajasthan

4. WATER SECURITY APPROACHS FOR RAJASTHAN

Water Security means regular access and equity to safe potable water for drinking, sanitation and hygiene thereby leading to an acceptable, physical, and social wellbeing. Water security is truly a basic human need in every sense. Water is not only inherently required for sustaining human life, it also serves as a vital link with all other ecosystems and any threat to water security is bound to adversely impact the other ecosystems. The trends of water scarcity and water use in the Rajasthan have prompted the administrators, researchers, planners and intellectuals to ponder over the problem which may become very acute for the people of the twenty-first century.

The problem of water crisis cannot be solved without stakeholder's participation (Grigg, 2008) and efforts should be made to get every citizen involved at the different water conservation schemes. Access to water for productive and domestic uses (industry, agriculture and other economic activities) has a direct impact on food security and society social and economic capital.

4.1. Water Requirements of State

Estimating water requirements is one of the prime importances for any planning effort to water security. Domestic Water requirement is typically made from groundwater, dams, canals, lakes, ponds, rivers, rooftop rain water harvesting and also treated waste water. Public Helth Engineering Department (PHED) has established norms for rural water supply of 100 liters per capita per day (lpcd) in Drought Development Programme (DDP) blocks of Rajasthan, 70 lpcd in non-DDP blocks, 135 lpcd in towns having a population of more than 20,000 and 100 lpcd in towns having a population of less than 20,000 (Water Supply and Demand by district 2014). State water plan has projected that the agricultural water requirement will be about 100 BCM, which obviously is not available from existing sources (Vision 2045, 2015). More than 80% of rural families keep livestock in their households. According to information from the Deputy Director, Animal Husbandry Department, Udaipur, the daily water consumption by different animals is as follows cows 65 lpcd, buffaloes 65 lpcd, sheep 6 lpcd, goats 5 lpcd, horses 60 lpcd, Asses 60 lpcd, Camels 65 lpcd, Elephants 150 lpcd and Poultry 0.25 lpcd, The present industrial water requirements have been estimated at 11.22 m^3 per ha per day of industrial area developed.

4.2. Drought Management

During the last century i.e. (1901-2002) it has been observed that frequency of drought ranges between 40% to 54% over the state. Table 2 shows the frequency and intensity of drought in various districts of Rajasthan. The drought experienced in recent years has brought on an environmental and socio-economic crisis in semi-arid areas. The impact of droughts on groundwater depletion was very sparkling in the hard rock regions of Udaipur, Rajsamand, Dungarpur, Bhilwara, Chittorgarh, Ajmer, Sirohi and Pali districts, as there are limited aquifer thicknesses available in such areas. In these districts, nearly 60 blocks have recently moved into the semi-critical, critical and overexploited stages. Also losses may extend to perennial trees, plantations, orchards and could also lead to depletion in fertility of livestock (Kumar et al., 2005). Drought management is very necessary step for water security and must be taken at technical, administrative, and political levels to encourage people participation in the drought management for optimum utilization of the available water resource. Proper drought management requires that all the rivers of India must be inter-linked and efforts must be made for drought control in arid region of Rajasthan.

Table 2 Frequency and intensity of droughts in districts of Rajasthan during 1901-2002

District	Number of years with droughts of different intensity				% of all drought years in the period
	Very Severe	Severe	Moderate	Light	
Western Region	**12**	**12**	**11**	**11**	**45.0**
Barmer	4	15	17	11	46.0
Jaisalmer	6	12	13	17	48.0
Bikaner	8	12	16	10	46.0
Sri Ganganagar	9	9	12	18	47.5
Churu	8	11	8	17	43.1

Nagaur	2	17	15	15	48.5
Jodhpur	5	16	16	18	53.9
Pali	7	12	19	14	52.0
Jalore	7	13	13	20	48.1
NE Region	**12**	**8**	**11**	**16**	**46.0**
Sikar	5	20	11	14	49.5
Jhunjhunu	9	15	12	12	47.0
Alwar	7	16	10	15	47.0
Jaipur	10	11	16	9	45.5
Ajmer	6	16	21	13	45.5
Tonk	9	11	10	15	45.9
Swai Madhopur	8	8	14	21	50.0
Bharatpur	9	13	11	12	44.5
Southern Region	**10**	**12**	**9**	**12**	**42.1**
Bhilwara	3	9	10	14	40.0
Chittorgarh	10	12	9	13	44.0
Udaipur	10	14	14	6	43.5
Sirohi	5	17	10	21	53.0
Banswara	11	14	13	9	44.7
Dungarpur	9	16	10	5	49.5
Bundi	7	16	13	11	44.7
Kota	8	16	11	11	45.5
Jhalawar	8	13	14	8	43.8
All Rajasthan	10	10	15	13	47.0

(Source: Rathore, 2005)

4.3. Rainwater Harvesting

Rain Water Harvesting (RWH) is one of the prime sources of fresh water and groundwater recharge especially in arid regions. Rajasthan has very rich tradition of water harvesting for drinking and livestock water requirement and for recharging groundwater purposes. Some structure is still in existence after long years. During rainy season, the people in the villages used to collect the rainwater in the vessels and use the same for household purposes including drinking as well as livestock and agriculturel purposes. Rainwater harvesting is being necessary for water security purpose at present time due to increasing water demand day by day not only for agriculture, but also for industrial and household purposes.

The accumulation and deposition of rainwater for reuse before it reaches the aquifer, has been made mandatory in state owned building of plot sizes more than 300 m^2 by the Central Ground Water Board of India. Khandelwal et al. (2014) estimated that if 50% of the resident houses and commercial building are taken up for rainwater harvesting, then 100% drinking water requirement could be met from RWH. This rainwater can also be stored in a pit to percolate downward through a recharge tube well. All newly constructed government buildings are to have rooftop rainwater harvesting structures. This must be strictly enforced and incentives must be created to encourage masses for the construction of domestic rooftop rainwater harvesting structures.

4.4. River inter linking

River inter linking will eliminate the periodical problem of droughts and floods and also provide water security. Presently country is affected by drought flood drought syndrome as nearly 1/3 area of country is drought prone and some part of the country under

Brahmaputra and Ganga river plain is flood prone. In the country a lot of damage occurs due to flood, whereas simultaneously other area may be facing critical shortage of water.

Floods are a recurring feature in the country, particularly in Brahmaputra and Ganga rivers, which has almost 60 per cent of the river flows of our country. Flood damages, which were Rs. 52 crores in 1953, have gone up to Rs. 5,846 crores in 1998 with annual average being Rs. 1,343 crores affecting the States of Assam, Bihar, West Bengal and Uttar Pradesh along with untold human sufferings. And another side, large areas in the States of Rajasthan, Maharashtra, Andhra Pradesh, Gujarat, Karnataka and Tamil Nadu are facing droughts. As much as 85 % of drought prone area falls in these States (NDWA, 2015).

The state has eight major river basins but Mahi and Chambal are only perennial rivers that receive water from catchments stationed outside the state. Water resources data simulated for each basin suggest that the internal surface water resources in the state during normal rainfall years could be better utilized only if there could be river interlinking (Narain, 2005). The transfer of surplus waters of Ravi, Beas and Sutlej to Rajasthan right upto Jaisalmer and Barmer through Indira Gandhi Nahar Pariyojana (IGNP) has provided power benefits, eliminated drought conditions, transformed desert waste land into an agricultural productive area by bringing irrigation and vegetation to about 2 million hectare area. Contribution in agricultural production due to implementation of the project is worth Rs. 1,750 crores annually (NDWA, 2015). Canal water is also available for domestic water requirements. The western part of Rajasthan and Indian military receive water from this canal. This project has miraculously changed the living standard and socio-economic conditions of the people in the area. The greater water availability with strong stakeholder's participation could prompt a preference for growing water-intensive cash crops. According to Kongre and Goyal (2013) The transportation of water through canals from the reservoirs and other revers are necessary for food security and water security and to meet other water demands.

Some adverse impact of river inter linking found by Goyal and Arora (2012) in Part I of IGNP area falling in Hanumangarh and Sriganganagar districts of Rajasthan, which is facing severe problems of waterlogging and salinity. They conclud that groundwater modeling is very useful tool for future predictions of groundwater levels for various proposed strategies to reduce waterlogging and salinity. Martin (2003) also warned that river inter linking without looking at the ecological impact may be very harmful for environment.

5. CONCLUSIONS AND SUMMARY

Inadequate water security is a very real problem in today's time for Rajasthan state, and this will only aggravate under future uncertainties. The Rajasthan state still has significant potential for conserving and harvesting water if an integrated water resources management approach is adopted judiciously, and proper policies and investment actions are implemented using recent technologies. Many deficiencies exist in the present system, including inefficiencies, lack of stakeholder participation, and unsustainable water use practices.

Participation of the stakeholders is essential in the process of water conservation and it is essential to educate masses so that they accept that water is a limited resource. A permanent effort needs to be made to support a very huge level of unity and cooperation among present and future water users. Some aspect for water security and integrated water resource management are

- Water security planning and implementation should be strictly follow at village, district and State levels.
- Financial and technical support for maintenance of pipelines and supply of safe drinking water
- Knowledge should be shared and networking with agencies across the world working on the same subject.
- Creation of recharge zones for rainwater harvesting
- Disaster management plan (floods and drought)
- Education, Information and communication should be increase (Water concern)
- Effective monitoring and cost-benefit evaluation (structures and plants)
- Recycling and reuse of wastewater for irrigation uses
- Incentives for Recycling, Reuse and Reduce
- Inter linking and cleaning of major rivers
- Promotion of drip and sprinkler irrigation systems in water stressed areas

REFERENCE

1. Ako, A.A., Eyong, G.E.T. and Nkeng, G.E.(2010) "Water Resources Management and Integrated Water", Resources Management (IWRM) in Cameroon, Water Resource Management 24:871–888 DOI 10.1007/s11269-009-9476-4
2. Census (2011). http://www.censusindia.gov.in/
3. CGWB (2015). "Ground water scenario of Rajasthan" Central

Ground Water Board.
4. CWC 2015, http://www.cwc.nic.in/
5. Davis, M.D. (2004) Integrated Water Resource Management in Chile: To Be or Not To Be. Critical Transitions in Water and Environmental Resources Management: pp. 1-14. doi: 10.1061/40737(2004)114
6. Falkenmark M (2001). The Greatest Water Problem: The Inability to Link Environmental Security, Water Security and Food Security, International Journal of Water Resources Development, 17:4, 539-554
7. Ferreyra, C. and Beard, P. (2007). Participatory evaluation of collaborative and integrated water management: Insights from the field, Journal of Environmental Planning and Management, 50:2, 271-296, DOI: 10.1080/09640560601156532
8. Gao, H., Wei T., Lou, I., Yang, Z., Shen ,Z., and Li Y. (2014) "Water saving effect on integrated water resource management" Resources, Conservation and Recycling 93 50–58
9. Giordano, M., and Shah, T. (2014). From IWRM back to integrated water resources management. International Journal of Water Resources Development, 30:3, 364-376, DOI:10.1080/07900627.2013.851521
10. Goyal, R. and Arora, A.N. (2012). Predictive modelling of groundwater flow of Indira Gandhi Nahar Pariyojna, Stage I ISH Journal of Hydraulic Engineering vol 18(2) pp 119-128
11. Grigg, N.S. (2008). Integrated water resources management: balancing views and improving practice, Water International, 33:3, 279-292, DOI: 10.1080/02508060802272820
12. GWP (2000) Integrated water resources management. Global Water Partnership, Stockholm
13. Hu, X.J., Xiong, Y.C., Li, Y.J., Wang, J.X., Li, F.M., Wang, H.Y., Li, L.L. (2014). Integrated water resources management and water users' associations in the arid region of northwest China: A case study of farmers perceptions. Journal of Environmental Management 145 162e169
14. Hydrogeological atlas of Rajasthan (2013). State ground water department Rajasthan
15. Khandelwal, P., Tiwari, K., and Goyal, R. (2014). Rooftop Rain Water Harvesting as part of IWRM Plan of Khuskera-Bhiwari Neemrana Investment Region. ETWQQM -2014 Conference Proceedings International Journal of Engineering Research & Technology (IJERT) pp. 145-149
16. Kongre, D.N. and Goyal, R. (2013). Prediction of Water Logging Using Analytical Solutions - A Case Study of Kalisindh Chambal River Linking Canal. Journal of Water Resource and Protection, 5, 624-632 doi:10.4236/jwarp.2013.56063
17. Kumar, R., Singh, R. D. and Sharma K. D. (2005). Water resources of India. current science, vol. 89, no. 5
18. Livestock census 2012, http://animalhusbandry.rajasthan.gov.in/livestock_census.aspx
19. Martin, C. (2003), Dams, Rivers and People. 1(2-3) March - April; also in Hindustan Times (New Delhi)10 February (http:// www.narmada.org/sandrp/apr2003_1.doc)
20. Morison J. I. L., Baker N. R., Mullineaux P. M and Davies W. J.(2007) "Improving water use in crop production" Phil. Trans. R. Soc. B 363, 639–658. doi:10.1098/rstb.2007.2175
21. Narain, P., Khan, M.A. and Singh G. (2005) Potential for Water Conservation and Harvesting against Drought in Rajasthan, India WORKING PAPER 104, IWMI
22. NWDA (2015), http://www.nwda.gov.in/index2.asp?slid=3&sublinkid=3&langid=1, Accessed in Sept 2015.
23. Olivier Petit and Catherine Baron (2009) "Integrated Water Resources Management: From general principles to its implementation by the state" The case of Burkina Faso. DOI: 10.1111/j.1477-8947.2009.01208.x
24. Rathore, M. S. 2005. State level analysis of drought policies and impacts in Rajasthan, India. Colombo, Sri Lanka: IWMI. 40p. (Working paper 93 : Drought Series Paper No. 6)
25. Rahaman, M.M. & Varis, O. 2005. Integrated water resources management: evolution, prospects and future challenges. Sustainability: Science, Practice, & Policy 1(1):
26. Rahaman, M.M., Varis, O. & Kajander, T. 2004. EU Water Framework Directive Vs. Integrated Water Resources Management: The Seven Mismatches. International Journal of Water Resources Development, 20(4): 565-575.
27. Roy S and Ophori D (2012) "Assessment of water balance of the semi-arid region in southern san joaquin valley California using thornthwaite and mather.s model", journal of environmental hydrology vol. 20
28. Singh, A.K., Eldho, T. I., and Prinz D(2002) Integrated watershed approach for combating droughtin semiarid region of India: A case of Jhabua watershed. Water Science & Technology, Vol. 46 pp 85-92, ©IWA Publishing
29. Stucki, V., Wegerich, K., Rahaman M.M., Varis O (2012) Introduction: Water and Security in Central Asia—Solving a Rubik's Cube. Water Resources Development, Vol. 28, No. 3,

395–397

30. TERI (2011). Rajasthan State Action Plan on Climate Change Government of Rajasthan.
31. Vision 2045 (2015). http://waterresources.rajasthan.gov.in/vision.asp
32. Water Supply and Demand by district (2014) Report # 4.6-IN-24740-R13-077